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SOME BACTERIAL DISEASES OF PLANTS

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BY

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SOME BACTERIAL DISEASES OF PLANTS

By WALTER G. SACKETT

FOREWORD

It is the purpose of this bulletin to call attention to some of the more common bacterial diseases of plants which are either present in the State or may be expected in the future, with the hope that the old adage, "To be forewarned is to be forearmed," may be of some avail. With one exception, the diseases here treated are well known in the Eastern and Central States, where they have caused immense losses to gardeners and fruit growers. Where remedies are known, they have been suggested, but it is the deep regret of the plant pathologist that for the majority of bacterial diseases no efficient treatments have been discovered and prevention is the only hope.

While the climatic conditions of Colorado may be said to be on the whole unfavorable to the development of diseases in plants, especially fungus troubles, the fact remains that there are some localities which have suffered heavily from causes traceable to bacteria. Nature has blessed this State with conditions which afford all that could be desired toward the natural prevention of bacterial diseases; the dry air, the limited amount of rainfall and the abundance of sunshine, all combine against the growth of germs.

The soil of Colorado is comparatively new so far as agricultural practices are concerned, and with the change in its character and fertility, brought about by continued cropping, we shall expect to find many of our cultivated plants becoming more and more susceptible to the attacks of microorganisms.

With the introduction of new plants, new varieties of old plants, foreign seeds, and strange nursery stock, it is not at all improbable that previously unheard of diseases will make their appearance.

Again, as the farming communities become more thickly populated and more new land is cleared and brought under cultivation, the danger of plant diseases spreading from farm to farm is greatly increased.

Plants and trees, like human beings and the lower animals, are affected with contagious diseases which spread from individual to individual, from field to field, and from ranch to ranch in precisely the same manner as any contagion is communicated from one member of a family to another. The more densely a city is populated, the greater is the danger from the spread of disease and the more stringent must be the laws which govern the sanitation of

that city. Quarantine must be established or an epidemic is sure to follow. Just so with diseases in our fields. It should behoove every farmer to see to it that his field is free from infection and to compel his neighbor to be equally vigilant.

The diseases treated are:

Bacterial Disease of Alfalfa, Page 4.
Pear Blight, Page 6.
Soft Rot of the Sugar Beet, Page 14.
Black Rot of Cabbage, Page 15.
Blight of Potato, Tomato, Egg Plant, and Tobacco, Page 19.
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Wilt of the Cucumber, Cantaloupe, and Squash, Page 22.

BACTERIAL DISEASE OF ALFALFA

PRELIMINARY REPORT.

In November 1906, Prof. Paddock* called attention to an alfalfa disease occuring in certain parts of Colorado, which was different from any previously described malady, and which, from all appearances, was not related to either leaf spot or mildew. Gross examination of the affected stems and roots and subsequent microscopic examination satisfied him that in all probability the disease was of bacterial origin. During the past summer, 1908, a careful study of the disease has been undertaken both with field and laboratory studies, and a technical bulletin is now in preparation, describing both the diseases and the causal organism. Our present investigations have confirmed the preliminary work of Prof. Paddock and have shown the cause of the disease to be due to a germ of the bacillus type.

DESCRIPTION OF THE DISEASE.—At a distance, the disease can be recognized by the short, sickly growth of the first crop and the marked absence of that rich, deep green color and succulent appearance of a thrifty stand. Many of the plants do not get over eight inches to a foot high by the time of the first cutting. A close examination of the stems shows them to be shriveled and blackened for two to three inches up from the ground. The infection seems to attack the plants next to the soil and to work up the stem. As the disease progresses, it produces a watery, semi-transparent, brownish appearance of the tissue which turns black with age. By running the thumb nail along the stem, it is possible to scrape up under the delicate surface skin a little yellowish, watery blister, the content of which is a sticky, stringy liquid, yellow in color, and alive with bacteria. This liquid frequently oozes out on the stems

*Press Bull. 28, Colo. Expt. Sta.

in little bead-like droplets and there hardens into small, amber-colored scales. Again it appears to dry uniformly over the surface, or just beneath it, and there produces a dark brown, resinous surface, which blackens with age. Such stems are very brittle and easily broken, which fact makes it almost impossible to handle the crop without an immense amount of shattering.

The leaves attached to the diseased part of the stem usually show the watery, yellow color at the base and especially in their tiny petioles. The leaves on those parts of the stem which are blackened are always dried up, yellow, and extremely brittle. The stipules at the base of the petioles are yellow and brittle, and show the disease before their corresponding leaves.

One year old plants exhibit blackened areas in the crown and black streaks running down into the tap root. As the plant grows older this blackening increases until the whole crown is involved, and either the crown buds are destroyed or the root is no longer able to perform its functions, and death follows.

So far as our present observations go, the disease appears to run its course with the first cutting, and those plants which have sufficient vitality throw out a good growth for the second and third cutting. Strange as it may seem, there is little or no trace of the blight during the remainder of the season, but in the following spring an aggravated outbreak may be expected. The disease apparently does not kill many plants the first year, but they begin to die after the blight has been prevalent more than one season, and after two or three years so many of them may be missing that the stand is practically worthless.

At present, we are at a loss to explain satisfactorily why the first cutting, only, should be attacked, unless it is that by pasturing cattle on the alfalfa field during the winter, the constant tramping splits open the crowns and bruises the young, tender shoots so that during the first irrigation, soil containing the disease germs is washed into this injured tissue. The weather conditions at this time of the year are, as a rule, unfavorable to a rapid, vigorous growth of the plant, and it is probably in a hyper-susceptible condition. This explanation is borne out, first, by the fact that the disease has not been observed to occur until after the first irrigation; and second, by the fact that since no cattle are allowed in the field after the first cutting, the young crown buds of the second crop have received no mechanical injuries through which they might become inoculated. Again, the plants themselves are in a more vigorous, resistant condition at this season of the year.

Future experiments alone will demonstrate whether it will be possible to prevent the disease upon the first cutting by keeping stock off the land during the winter and early spring, and by so doing

eliminate mechanical injury to the plants during the susceptible period.

Inasmuch as the disease seems to be clearly a soil trouble, the only practical method of controlling it is by the introduction of resistant varieties. To this end we have planted some twenty-seven different varieties of alfalfa on sick land with the hope of obtaining one or more blight resistant strains. This side of the work was begun by Prof. Paddock two years ago, and after two years' trial under field conditions, we have obtained some very promising results with two of the varieties tested. Whether these will continue in their resistance during the next few years remains to be seen.

PEAR BLIGHT. (*Fire Blight*)

A description of Pear Blight may seem uncalled for to the fruit grower who is sufficiently familiar with the malady to recognize it at first sight and to whom the mere suggestion of the name recalls immense financial losses, but to the farmer, who has three or four trees around his house for his own use and who has not had his attention called to the disease in such a material way, some consideration of the subject may be given with profit. Not only should the farmer become acquainted with the symptoms of the disease and learn and practice methods of prevention and eradication for the sake of his own trees, but also for the sake of his neighbor's orchard as well. One infected tree in the community may mean the ultimate loss of vast orchards for miles around.

Of all the diseases which affect our fruit trees, there is none, perhaps, which is so universally dreaded by the orchardist as the pear blight. While the ravages of the disease are worst upon the pear, from which fact the disease derives its name, its attacks are not confined in any sense of the word to this tree alone. Many varieties of the apple, quince, apricot and plum, together with the mountain ash, service berry and several species of hawthorne, have suffered severely from the same cause. Especial attention should be called to the part which such ornamental trees as the mountain ash and hawthorne play in harboring the germs of blight. If these trees become infected and are allowed to go unnoticed, it is obvious that it is useless to attempt to stamp out the disease in adjacent fruit trees or a nearby orchard, since a constant supply of germs will be furnished by the ornamental plants mentioned, with which to reinfect the fruit trees. If such conditions are found to exist, but one thing remains to de done—remove the offending individual bodily and burn it.

The name *fire blight* is especially good because it is at once suggestive of the symptoms of the malady. To one not familiar with the disease, it can be recognized at first sight by the brown and

subsequent blackened appearance of the young leaf tufts and flower clusters; some of the leaves may be only partly blackened, while the greater part of the blade remains green; the young twigs show a blackened, shrivelled bark, resembling very much green brush which has been only partially burned. The blight makes its appearance early in the spring shortly after the blossoms have fallen and works rapidly back from the blossom clusters an inch or more a day. It soon involves the tender, succulent twigs and may ultimately destroy the whole limb. If the diseased wood be cut with a sharp knife, a dark ring between the bark and the wood will usually be seen. This is a further indication that the tree is affected. This ring of tissue, now blackened, is known as the *cambium layer*. It is here that a rich and abundant supply of food is to be had and, quite naturally, what is good for the growth and development of the tree is equally as nourishing for the germs. So we find, upon microscopic examination, that this blackened cambium tissue has lost its normal color and appearance and instead of the cells being almost white in color with a clear, colorless liquid within, they are brownish, more or less broken, and all through this mass of broken down tissue is a straw-colored liquid, clouded with millions upon millions of germs. These germs is growing here have dissolved out the starchy constituents of the plant tissue and literally eaten up the cells to such an extent that the circulation of the plant is destroyed. The rapid progress which the disease makes is to be accounted for, in a measure at least, by the fact that the causal microorganisms have the power of very rapid movement; that is, we say they are motile. Thus endowed, they are persistently swimming about in the protoplasm of the cambium, dissolving and boring their way into new, healthy tissue where a fresh supply of food can be obtained. As the disease progresses and the smaller limbs show the infection, the tender bark may crack and a thick, black, sticky gum, alive with germs, may exude; soon afterwards the bark becomes dark colored, hardened and shrunken.

The disease makes its greatest progress during the actively growing period in the spring when the tree is putting forth a multitude of young, tender twigs and the new tissues are gorged with sap. Just such conditions as these favor the growth of the blight microorganisms, so it is easy to see why the disease is worst at this time of the year. As the season advances, the plant tissues harden, less sap is flowing, and conditions for germ life become less favorable. As a result, by the middle of summer the active progress of the blight is checked by natural causes, but the disease is still present in what may be termed a latent form. In this stage it sometimes remains through the balance of the season and, protected by the bark of the twig or limb, it may live through the winter, giving

rise to what is known as holdover blight. It is the germs which exist in this holdover blight which serve to reinfect the orchard the following spring. In most instances, however, the germs die out of their own accord during the winter and leave the whole tree or portions of it free from the infection of the previous season. Although the disease is usually at its best in the early spring, the writer has in mind an orchard in Central Ohio, numbering some four hundred trees, in which the blight assumed its most severe form about three weeks previous to picking the fruit. Up to the middle of August there were but three or four badly infected trees, and within three weeks from that time, every tree in the orchard was suffering from a severe attack. The fruit had to be picked two weeks before time in order to prevent all from being ruined by the blight.

Pear blight is variously known as pear blight, apple blight, fire blight, twig blight, blossom blight, and body blight, the name depending upon the species and portion of the tree affected. If the blight attacks the larger branches and trunk where there has been some bruise or mechanical injury, the symptoms are much the same as what is known as sun burn or sun scald. This form of the malady is known as rough bark or body blight.

It is only within comparatively recent years that we have known that the cause of apricot and plum blight is the same as that of pear blight. Prof. Paddock,* in describing the disease as it occurs on the apricot, says:

"At this time many of the fruits were attacked, the diseased areas varying in size from a spot an eighth of an inch in diameter to irregular areas that involved three-fourths of the fruit. The skin over these places soon became nearly black in color and shrunken as the tissues were consumed till the outline of the pit was disclosed. These discolored areas were always definitely outlined and bordered with a zone of watery appearing tissue usually about an eighth of an inch in width. The latter was green in color and as hard as the sound flesh.

"The smaller spots where the disease had evidently just started, invariably surrounded a lenticle, thus indicating that the disease gained entrance to the fruit through these openings.

"The injury to the twigs may be described best by saying, that they resembled closely, blighting pear or apple twigs. So far as noticed only tender twigs of the current season's growth were attacked. These were shrivelled and discolored from a few to several inches in length, and small drops of sticky fluid were occasionally found on their surface and upon the shrivelling leaf-stems. The discolored outer bark blended gradually into normal appearing tissue, but the inner bark was discolored for some distance below any external evidence of disease."

HISTORY.—The disease is by no means recent, for it dates back to the time of William Denning, who first reported the trouble from the Highlands of the Hudson in 1770. He described it fairly well and ascribed the cause to a borer in the trunk of the tree.

The oldest book on American Fruit Culture, published in 1817

*Bull. 84, Colo. Expt. Sta.

by William Coxe, gives a very accurate description of the disease. From this early date up to comparatively recent times, horticultural literature has been crowded with numerous extravagant theories of the cause of the blight. Even today we occasionally find men who hold to one or another of the old ideas. It may be interesting to know what some of these were:

1. Insects.
2. Rays of the sun passing through vapor.
3. Poor soil.
4. Violent changes in the temperature of the air or the moisture of the soil.
5. Sudden change from sod to high tillage, resulting in surplus of sap.
6. Effect of age.
7. Autumn freezing of unripe wood, which makes a poison destroying the shoots and branches the following spring.
8. Electricity in the atmosphere.
10. Fermentation of sap.
11. Absence of certain mineral matters in the soil.
12. Something in the air which is carried from place to place.
13. Fungi.

ORIGIN AND SPREAD.—In 1878, Prof. W. T. Burril, of the University of Illinois, succeeded in finding a kind of bacteria which he believed to be responsible for the disease.

The blackened twigs and sticky exudate were found to be alive with germs, which are very small plants, so small, in fact, as to be seen only with a very powerful magnifying glass such as we find in the compound microscope. Some idea of the size can be gotten when we know that it would require 25,000 germs placed end to end to make one inch.

By taking some of this gummy material, which contains the bacteria, and inserting it into a healthy twig through a small cut, it was demonstrated that the inoculated twig took the disease and that therefore it could be spread from one tree to another, or was what we call an infectious disease. It was also shown that this same gummy material from the pear could produce the disease on the quince and the apple. This experiment is very simple and can be tried by anyone who is interested in the infectious nature of the blight. It was argued by some that it was not the germs which produced the blight, but rather the gum which was injected. To meet this objection, the germs were grown in a suitable medium such as beef broth and a quantity of the pure organisms were inoculated into a healthy twig. The results were very conclusive, for the twig soon died, showing that the germs by themselves had the power of killing the plant.

The question which we now have to answer is, where does the blight originate when our orchards have never had it before? Where does it come from? It has been shown quite conclusively that it is

not carried on the wind, neither is it traceable to the soil. Ants, flies, and possibly bees may feed on the gummy material which runs out from the cracks in the diseased wood, and knowing that this exudate contains millions of germs, it is only reasonable to believe that these insects carry the disease on their feet and bodies to the healthy trees. Alighting on a delicate flower cluster, they crawl deep down after the so-called honey or nectar in the blossom and here many of the blight germs are brushed off and left in contact with the tender blossom. Through these honey ducts or nectaries the bacteria gain entrance to the plant. Once favorably situated, they multiply and move down the twig between the bark and woody cylinder through the growing layer. It is in this way that a large percentage of the cases originate. As further evidence of this method of infection, we may cite the investigations of Mr. M. B. Waite, of the U. S. Department of Agriculture, who found the germs developing in the nectar of the blossoms and also discovered them adhering to the mouth parts of honey bees after they had visited infected flowers. He further observed that, in many cases, trees which did not blossom were free from blight.

Again, the germs may gain entrance into the tender shoots through insect bites in the bark, for, although the opening may be no larger than a pin prick, myraids of bacteria can find a temporary dwelling place in this wound and may soon spread through the whole member. Lastly, the infection may enter the large limbs and trunk of the tree by some scratch or bruise in the protecting bark which has exposed the susceptible growing layer beneath to the visits of germ-laden insects.

Thus we see that pear blight is caused by a germ to which the name *Bacillus amylovorus* (Burrill) has been given, the meaning of which is starch destroying. We see that it is spread from one tree to another by different insects, and that the germs may gain entrance into the plant in any of three ways: First, and most important, through the blossom; second, through insect bites in the tender shoots; third, through mechanical injuries to the bark of the limbs and trunks of the trees.

CONDITIONS FAVORING THE DISEASE.—Although the knife is our only hope of exterminating the blight, there are undoubtedly conditions which favor the disease.

It is a matter of common observation that climatic conditions have a marked influence; warm, moist weather with a large amount of rainfall favors it, while bright, dry, cool weather tends to check it. That is, the former conditions are advantageous to the growth of the germs, while the latter are unfavorable.

High cultivation, rich soil, heavy manuring, the use of large

quantities of commercial fertilizers containing a great deal of nitrogenous material and heavy pruning all tend toward the growth of tender, succulent shoots. It is in this sort of plant tissues, gorged with sap, that the blight germs can grow and multiply most rapidly. Biting insects whose mouth parts are contaminated with the causal microbes, are most partial to these juicy shoots and leaves, and their bites often serve to infect the tree.

It is evident, then, that vigorous, healthy, rapidly growing, too well cared for orchards are more liable to the disease than others, and since these are factors which the grower can control, it is he who must strike the happy medium which will not permit the trees to suffer and yet will not give ideal conditions for the development of the germs.

PREVENTION AND TREATMENT.—The treatment of fire blight is of two kinds—the one, preventative; which aims at making the tree resistant to the attacks of the disease; the other, curative, which is intended to exterminate the harmful microbes and thus prevent their spread.

1. It is obvious, if we are to render our trees resistant to blight, we must avoid those conditions which increase the predisposition to the disease. We have already mentioned the most potent factors in the propagation of blight as high cultivation, rich manures, commercial fertilizer high in nitrogenous material, excessive soil moisture, and high pruning. In short, anything which favors the rapid growth of tender, succulent shoots should not be practiced. It is understood, of course, that these suggestions are not to be followed without reason, or the trees will suffer from troubles other than the blight. The trees should be allowed to ripen their wood, and to this end the grower must use some means which will limit the moisture in the soil. It is recommended that some good cover crop, such as oats, be used for this purpose in localities where the necessary moisture is supplied by rain and where the growing period is apt to be prolonged into the late summer because of excessive soil moisture.

In irrigated regions, where the water is entirely under the control of the grower, the problem of ripening the wood and preventing late succulent growth is a comparatively simple one. Good results have been obtained in eradicating blight from afflicted orchards by withholding water altogether for long periods and also by limiting the amount supplied to the minimum necessary to keep the trees alive.

Prof. Paddock* gives the following account of an orchard suffering with pear blight, which had not received any water for two

*Unpublished Notes

and a half years and which illustrates in a practical way what the withholding of water has done toward the eradication of the disease in a natural way:

"The writer had an opportunity of studying an orchard during the summer of 1904, which had been without water for two and one-half years. The effect of this enforced drought on checking blight was very marked, and it also showed that pear trees can exist in this location for a considerable period without irrigation or cultivation. These results would probably be the same in all of the pear growing sections of Colorado. * * * * At the time of my visit, June 25, 1904, many of the trees were still in good condition. This was especially true of the Winesap apple. The Jonathan trees were still in condition to be saved, but they were less vigorous than the Winesaps. Most of the Ben Davis trees were still alive, but the majority of them had put forth few or no leaves. About one-half of all of the apple trees of all varieties were dead, as well as most of the peach and plum trees.

"But the most remarkable, was the appearance of a block of eight-year-old Bartlett pear trees. Most of them were still in a fairly vigorous condition. Some of the twigs of the previous season's growth measured fourteen inches in length. The average of the current season's growth was about four inches, and quite a little fruit had set on some of the trees.

"The inspector, Mr. H. E. Mathews, had visited the orchard each season and he found that in 1902, blight was quite abundant in the pear trees and some of them died from its attacks. The following year there was still a good deal of blight, though there was much less damage than before. At the time of my visit, June 25, 1904, there were but few twigs in which the disease had been active that season and the germs were apparently dead. * * * * These results show that the germs of blight do not thrive in slowly growing trees and, in fact, that the disease may be eradicated by prolonged drought. They also show that pear trees will remain in good condition for a considerable period without irrigation or cultivation. But just how far this could be carried in actual pratice remains to be seen, but one cannot help but surmise that bearing pear orchards might be successfully handled without irrigation, depending upon cultivation, or lack of it to regulate the water supply."

2. With a disease working as this does in the juicy part of the stem between the bark and the wood, there is no chance of reaching the trouble by means of sprays, for, unless the chemicals come in contact with the bacteria, spraying is futile.

The knife and saw remain as the only effective remedies. We must cut out and burn all affected twigs, leaves and branches, not only from the pear but the apple, quince and related species as well, so that there will be no infectious material near by for insects to carry into the blight-free orchard. It is very essential in cutting out the diseased branches to cut well below the discolored part, as the bacteria are usually far below this region. The discoloration does not appear until after the bacteria have been at work some time, so that even if all the blackened wood were removed the seat of the trouble would not have been reached, and the germs would live on in the apparently healthy stump, soon to cause another visible outbreak of the blight. The affected branches should be cut back all the way from ten to fifteen inches below the discolored wood, and if the branch be a large one, more than one-half inch in diameter,

the cut surface should be protected from wound rots by painting. Either lead and oil paint, or shellac wash, or grafting wax may be used for this, but the lead and oil paint is cheaper and less liable to crack than the others when exposed to the sun. The question may be asked, "When is the proper time to do the cutting?" The writer would answer, "Whenever the blight appears." Trimming out the diseased parts may be done at any time in the late fall, winter and spring. The most favorable time, however, is in the autumn after the leaves have fallen, for then the blighted twigs become very conspicuous by the dead leaves still hanging to them. It is not advisable to postpone the cutting until the growing season, for at that time there is great danger of overlooking new cases which are constantly occurring owing to the lack of development so early in the season. If the entire tree is affected, there is little hope of saving it and the best procedure is to grub it out and burn the whole tree. Too much stress cannot be laid upon the complete destruction of the diseased wood, for our only hope of stamping out the blight lies in removing the source of the infection. A single twig left on the ground unburned may mean the loss of the whole orchard.

The knife and the saw used must be sterilized after each cut in order that the disease germs clinging to the instrument may not be carried to the healthy parts of the tree. This can be done by passing the knife several times through a flame, or it may be dipped into either a 5 per cent. solution of carbolic acid or a 1-1000 solution of mercuric chlorid, made by dissolving 1 part by weight of mercuric chloride in 1,000 parts of water to which 2 parts of hydrochloric acid have been added.

A careful inspection of the orchard should be made in the winter and spring before the blossom season, in order to destroy any new cases that may have developed since the previous examination.

The greater part of the blight will be eradicated by one careful winter and spring cutting, and if this be done and done thoroughly, the disease can be entirely controlled.

Susceptibility of Different Varities.—So far as we know at the present time there are no varieties that are entirely immune to the disease. Mr. O. B. Whipple, in charge of the fruit investigations of the Colorado Experiment Station on the Western Slope, state that among the pears grown in that locality, the Bartlett, Easter, Flemish Beauty, Clapp's Favorite, Clairgeau, Howell, and Sheldon suffer worst from the blight, and among the more resistant varieties may be mentioned the Anjou, Kieffer, Seckel, Mt. Vernon, Garber and Suduth. The most susceptible apples found in this same region are the Tolman Sweet, Peewaukee, Transcendent (Crab), Jonathan, Red Mountain, and Winter Banana.

Among the apples, the crabs in every case seem to take the disease most readily, but even here there are some which are freer from blight than others. It has been observed that the same variety in different localities and under different climatic conditions will exhibit different degrees of resistance. An earlier publication of the Colorado Experiment Station* cites one case in a certain locality where Martha and Whitney crabs were grown alternately. The Whitney trees were either all dead or dying, while not one of the Marthas was affected. However, in other localities the Marthas had succumbed to the blight.

In selecting trees we should be guided by local experience and choose the varieties which have done best in our locality.

SOFT ROT OF THE SUGAR BEET.

Although this disease has not yet been reported in this State, it is not at all improbable that it will make its appearance in due time as the acreage put out to sugar beets increases from year to year. The soft rot, as it occurs in Nebraska, was first observed in 1902 by Metcalf and Hedcock,† who have isolated the specific germ *Bacterium teutlium* (Metcalf), which is the cause of the trouble. Beets affected with the rot show the lower half badly decayed and the rotting part honeycombed with "pockets," or cavities filled with a slimy, stringy fluid, colorless and sour smelling. The vascular bundles remain intact, while the tissue surrounding them is usually consumed. The normal color of the beets differs so that it is difficult to give any hard and fast color characteristic, but when affected the tissue first shows a yellow, changing to a clay color or gray; later these colors gradually darken. In some cases beets that are badly rotted show no discoloration, while others in the early stages are very dark. Above ground the beets appear normal.

A microscopic examination of viscid liquid that fills the cavities of the rotting tissue shows millions of bacteria, which when grown later in pure culture and inoculated into healthy beets produced symptoms typical of the disease.

The germs gain entrance into the beet through wounds and abrasions in the skin, and there is good reason for believing that nematodes are responsible for many of the inoculations. So far as experimental work goes, there is no evidence that infection can take place, except through cuts or scratches in the outer surface of the root. In the field, the disease has been observed to progress most rapidly under warm and wet conditions; more mature beets are affected more severely than the younger ones, probably due to the larger amount of sugar present.

*Bull. 41, Colo. Expt. Sta.

†17th Annual Report Neb. Expt. Sta.

If the beets are stored in silos and rotting sets in, they should all be inspected and the decayed ones put in a pile by themselves, so that all will not contract the rot. Cold storage does not seem to have any influence on checking the trouble, for even at low temperatures the germs continue to grow and produce havoc. It is recommended that beets from sick soil be thoroughly sunned and dried before storing, inasmuch as the dessication and sunlight have been found to be very detrimental to the growth of the germs.

Prevention is the only remedy that can be suggested at this time. Grow beets on relatively dry ground, if possible, and plant corn or some other suitable crop on former beet ground where the excess of moisture can do no harm. Our greatest hope of controlling this disease, as well as others, is by breeding up some resistant variety and, by careful selections, secure a strain which can be planted on wet land and yet remain immune. There is no question but that such resistant varieties will be forthcoming in the near future now that the scientific world is so wide awake to the wonders of plant breeding.

BLACK ROT OF CABBAGE.

The black rot of cabbage is to the truck producer what pear blight is to the fruit grower; in fact, it may be considered far worse, for on the one hand there is only the loss of the crop, while on the other, not only is the cabbage destroyed, but, in addition, the soil on which it has been grown may be so inoculated that it will be practically useless to attempt to raise the same crop on the same field with any degree of success for a number of years. While this condition of the soil exists almost universally in the East, there seem to be exceptions to it in this State, since Prof. Paddock reports that in certain localities in Colorado he has grown cabbage successfully on land which was badly infected the previous season.

Bacterial examination of diseased plants has shown the sickness to be due to a kind of germ, *Pseudomonas campestris* (Pammel, Smith). The disease is by no means confined to the cabbage, but attacks other cruciferous plants such as cauliflower, collards, kohl rabbi, kale, brussels sprouts and broccoli. It has also been reported as occurring in turnips, rutabagas, wild radish and mustard. It is widely distributed in the United States, having been found most prevalent east of the Mississippi River. In 1901, Prof. W. Paddock reported it from Colorado. Previous to 1899, we do not hear of the black rot in Europe, but the investigations of Harding,* confirmed by foreign workers, show the disease to be wide spread and of long standing. England, Holland, Denmark, Austria and Switzerland are mentioned as constant sufferers from the malady. This

*Cent. f. Bakt. II Abt. Bd. VI., pp. 305-313 (1900).

is peculiarly interesting, since a few years back a great deal of our cabbage seed was imported from Holland and Denmark. The comparatively recent discovery of the infection in Europe is probably due to the better methods of diagnosing the disease than formerly, rather than to recent appearances of the trouble. Cabbage growers of Europe have observed it for many years, it seems, but they were accustomed to associate the cabbage worm with the rot, rather than the true bacterial cause.

The disease can be recognized by the dwarfed, one-sided growth of the plants and in some cases, failure to produce heads. Sometimes the head will rot and fall off, but this is not a necessary accomplishment of the disease, for this symptom, together with the bad smelling head, may be due to the work of other bacteria which are living on the tissue already weakened by the true black rot organism. In the early stage of the disease, the leaves show a withered, dried appearance along the margin, followed in time, by a yellowing. The small ribs that lead to the mid-rib are usually blackened first, and ultimately the larger ones and the mid-rib succumb. On cutting across the stem of an infected leaf or sick stalk, one can see the blackened ends of the fibrous strands, known as the fibro vascular bundles, which lead from the stalk out into the leaf and supply it with water and soil foods. A microscopic examination of these vascular bundles will show the tiny tubes of which they are composed to be alive with germs. As soon as these foods and water channels are destroyed, the blade of the leaf is no longer able to get the subsistance required and dies. Diseased leaves usually fall prematurely, leaving a long, naked stalk with a tuft of leaves at the tip. The old leaf scars will show the ends of blackened strands corresponding to the diseased fibro vascular bundles in the leaf.

It has been found* that the most common method of infection in the field is through the very small water pores scattered over the blunt teeth on the margin of the leaf. It is by these water pores that a part of the soil moisture that is taken up by the root system escapes from the plant as water vapor, but if the surrounding atmosphere is very moist, there will be no evaporation and the water will be seen to accumulate in tiny droplets just over the pores. However, if the soil is very dry, even though the air is moist, we do not have these water beads formed. They can be seen frequently in the early morning on the surface of the leaves and are frequently mistaken for dew. It must be borne in mind that the air is always filled with dust and numerous bacteria, and among these there are almost certain to be the germs of black rot, especially if

*Russel—Bull. 65, Wis. Expt. Sta. Farmers' Bull. 63, U. S. Dept. Ag.

the wind is blowing over a sick field carrying with it fragments of rotting plants and infected soil. These germs are in the beads of moisture, referred to above, and finding a comfortable lodging place and abundant food and water supply, they multiply very rapidly, and being able to move about, soon find their way down through the water pores into the veins of the plant. Here they continue to multiply and work toward the stalk, leaving behind them the blackened veins and withered blades. The germs may also gain entrance by means of the bites of gnawing insects and again by way of the broken roots at the time of transplanting.

There is no question but that in many cases the plants are taken from the seed bed in a diseased condition and when transplanted into the field spread the germs through the soil, rendering it unfit for cabbage growing in the future. When the source of the infection is confined to such a limtied space as the seed bed, it is possible to sterilize the soil to a depth of five or six inches by covering it with brush and cord wood and burning it, the heat produced penetrating sufficiently deep to kill most of the surface bacteria, as well as troublesome weed seeds. This is a very common practice with tobacco growers and has met with great success wherever employed. If this is not practicable, the seed bed should be located in a new place each year and where cabbage has never been grown. It is only reasonable to suppose if plants are in a good, vigorous condition when transplanted into a "healthful" field, their chance of living is vastly greater than if sick from the start.

When stable manure is used for fertilizer, every precaution should be taken to keep infected cabbage refuse from getting into the manure, for in this way the whole heap will become infected with the rot germs and when it is spread on the field the entire plat will become inoculated. One of the worst plant disease epidemics on record was caused in this very way. The writer refers to the present watermelon wilt in North Carolina, South Carolina, and Georgia, where melon growing for the past six years has been practically abandoned by the smaller producers because of the ravages of the wilt. The only safe way to dispose of refuse is to burn it.

It has been demonstrated experimentally by Harding,* Stewart, and Prucha that the cabbage seed itself is contaminated with the black rot germs and that some of them could live over winter on the seed and become the source of infection to the young cabbage plants. They advise disinfecting the seed before sowing by soaking it in a 1-1000 solution of corrosive sublimate† for fifteen minutes,

*Bull. 251, N. Y. Expt. Sta.

†Corrosive sublimate. See preparation of mercuric chloride described under Pear Blight.

or in formalin, one pound in thirty gallons.

The removal of sick leaves in the early stages of the disease is practiced by some growers with success. Others have tried this preventative and found it to be a complete failure. The investigations of Stewart* and Harding condemn this practice and prove quite conclusively that the method is not only harmful to the plants, but also worthless. The treatment fails, they say, because,

"The removal of so many leaves checks the growth of the plants; infection occurs by way of the roots as well as through the leaves; infection may occur at the base of the leaf close to the stem and get into the stem unobserved; the germs of the disease are so widely and so abundantly distributed that it is useless to try to stamp out the disease by the removal of diseased material."

Warm days, cool nights and frequent showers seem to accelerate the rot. Smith† is inclined to think that cabbage planted late is less susceptible than that which is planted early. In selecting cabbage for producing seed the following season, care should be taken to pick out only those plants which are absolutely free from the infection.

When cabbage is to be stored over winter, the heads should be examined critically and any diseased ones rejected or kept by themselves. The room or store house must be kept cool, below 40° F., and must have uniform ventilation.

It is a matter of common observation in the Eastern States that when cabbage is grown year after year on the same piece of land, there is a notable increase in the amount of rot. In the first place, such a method is not to be recommended from an agricultural standpoint, since it violates the important principle of crop rotation, and further, if it becomes necessary, because of limited space, to continue using this land, our only hope of getting rid of the disease is to grow crops other than members of the cabbage family for five or ten years and longer. During this interim the land must be kept free from all cruciferous weeds which harbor the bacteria, especially the common wild mustard.

If possible, cabbage should be set each year on ground which has not been planted to it for some time, or which has been in sod several seasons, or else cultivated to crops which are not affected by the rot. The one important thing for the gardener to observe if he would be a successful cabbage grower, is to take the utmost care to keep his field from becoming infected, and if once infected not to spread the malady over his whole farm.

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*Bull. 232, N. Y. Expt. Sta.

†Farmers' Bull. 63, U. S. Dept. Ag.

BACTERIAL BLIGHT OF THE IRISH POTATO, TOMATO, EGG PLANT AND TOBACCO.

Dr. Erwin F. Smith,* Bureau of Plant Industry, U. S. Department of Agriculture, has shown that a single species of bacteria, *Bacillus solanaccarum* (Smith), has the power of producing a blight or wilt in a number of plants of the potato family. Among the common ones attacked may be mentioned the Irish potato, tomato, pepper and egg plant. In 1903, Dr. F. L. Stevens† and the writer published an account of what appeared to be a bacterial wilt of tobacco in Granville County, North Carolina, to which the name Granville Tobacco Wilt was given. The very recent work of Dr. E. F. Smith‡ confirms this finding and further shows the cause of the disease to be none other than the organism which produces the potato blight. Several common weeds, such as the horse nettle, jimson weed and ground cherry, are also susceptible to the disease.

The blight manifests itself in the vines by a sudden wilting, either of a part or the whole. The stems usually wither, turn yellow and finally black. Young plants appear to contract the disease more readily than old ones. By cutting across the affected stem one can see the characteristic brown or black, woody tissue in which the bacteria are at work. A section across the sick vine just at the surface of the ground, or a little below, will usually show, in addition to the blackened ring, a considerable quantity of a slimy, viscid liquid oozing from the blackened parts, especially if squeezed between the fingers. This is particularly true if the soil is rather moist. Microscopic examination shows this liquid to be swarming with the bacteria, which cause the trouble. It frequently happens in the early stage of the disease that the blackening seen in the cross section of the stem will not appear as a continuous ring, but only as one or two spots. If the vine is slit lengthwise through one of these spots, a blackened streak will usually be found running the whole length of the stem and finally out into the branch or leaf which showed the wilt. The germs appear to live in the soil and gain entrance to the plant through the root or underground stem, and once within the tissue they clog up the water tubes and later on destroy the conducting vessels so that no water can be transported from the soil to the branches and leaves and, as a result, we get the characteristic wilting. The tubers from sick plants show a distinct ring of discolored tissue a short distance from the outside of the potato.

Fungicides are of no value in treating this bacterial disease

*Bull. 12, Div. Veg. Path., U. S. Dept. Ag.
†Bull. 188, N. C. Expt. Sta.
‡Bull. 141, Part II, Bur. Plant Industry, U. S. Dept. Ag.

since the germs are inside of the plant, as well as in the soil, and so far as our present knowledge goes, there is no practical method of sterilizing soil in the field. Prevention is the only remedy. Do not use diseased tubers for planting and avoil planting on potato-sick-land as well as on land which has had diseased tomatoes or egg plants.

This disease must not be confused with the fungus blights, known as early and late blight, which respond quite readily to spraying with Bordeaux mixture. In this case, the organisms which cause the blight grow on the outside of the vines and can be easily reached and destroyed by the spraying mixture.

The symptoms of the blight in the tomato and egg plant are much the same as those for the potato. The vines wilt as if suffering from too hot sun or lack of water. Decay of the stems and branches soon sets in, resulting in the destruction of the plant.

Here, too, spraying has been found useless, for the cause of the disease is deep seated within the tissue and beyond the reach of any germicide. Insects, undoubtedly, play some part in carrying the germs from plant to plant and thus spread the trouble, but the soil seems to be the principal medium of infection. What has been said in connection with the potato may be said about planting tomatoes and egg plants on land that has had diseased specimens of the potato family.

If the disease is not too general, it is possible to control its spread by removing the dead vines with the roots from the field and burning them. It is of utmost importance that the vines be destroyed and not thrown down carelessly to start the disease in a healthy part of the field. Remember that you are dealing with a contagious disease and it is your duty to keep it from spreading. One sick vine in your field this year may mean the loss of half your plants next year. Numerous cases have been reported where soil diseases have been carried from farm to farm, up and down the road by the infected mud that adheres to the wagon wheels. The greatest care should be exercised in plowing and cultivating not to drag sick vines over healthy soil, for by so doing the disease is spread, and what might have been a mild attack is aggravated to such a degree that a general epidemic results. Tools should be thoroughly cleaned before going from an infected field into one free from the disease and, as a further precaution, they should be disinfected by washing or dipping them into a 5 per cent. solution of either carbolic acid or copper sulphate, commonly known as blue stone. It is important that the gardener's shoes, as well as those of his horse, be free from clumps of infected soil before going into a new field.

There is a common practice among some farmers of hauling

the soil that has washed down a hillside back up onto the shallow places of the farm. If this is done, one should be very certain that the hillside from which this soil has washed is free from all plant diseases, for the writer is familiar with several instances where infection has been spread over healthy land in this way.

Where no remedy can be given, it is clear that our only hope of controlling a disease is by preventing its spread. By observing the foregoing suggestions, it is believed that the most serious plant disturbances can be prevented to a great extent, or at least controlled.

BACTERIOSIS OF BEANS.

Frequently the foliage, stems and pods of the common beans, as well as the Lima bean, are preyed upon by a bacterial disease, *Pseudomonas phaseoli* (Smith), known as Bacteriosis. The symptoms are such as to make it readily distinguishable from all other maladies to which the bean is heir.

There appear on the different parts of the plant, especially on the leaves, large, watery, brown patches or blisters that soon dry up and cause the tissue to become brittle and to curl, leaving the foliage ragged and good for nothing. The pods seem to furnish the best food supply for the microbes and it is here that we find the disease at its best. Small discolored spots appear at first, which spread very rapidly and produce large lesions with pink or reddish brown borders, and which have pale yellow or amber colored crusts over the affected areas. This crust is due to the accumulation of myriads of amber colored bacteria which have formed a layer over the broken down tissue. After a time the pod rots and the beans are worthless.

Warm, wet weather seems to favor the disease, for the germs grow best under these conditions, and the beans at this time produce succulent growths, which are more readily attacked. Rain and dew are doubtless agents in spreading the germs from one part of the plant to another by washing them from old lesions onto unaffected parts. Insects play an important part in disseminating the trouble, consequently any measures which tend to check these pests will aid in controlling bacteriosis. The distribution of the disease is further effected by dead vines and leaves carried on the wind; by the soil, and through the seed. New land which has never grown beans seems to be freer from the disease than old, and should always be used when available.

The seed used in planting should be selected by hand and all the lighter ones discarded, since experiments show that diseased seeds are less dense than sound ones. As yet no satisfactory method has been found which can be recommended for treating the seed to destroy the causal microbe which does not lower the viability of the seed.

Inasmuch as the germs of bacteriosis work on the outside of the plant, it is possible to reach them with a fungicide and spraying with Bordeaux mixture upon two and three-inch plants, followed by the same ten days later and again after blossoming. Dr. Halstead uses a Bordeaux mixture of the following strength: Copper sulphate, 6 pounds; lime, 4 pounds; water, 60 gallons.

Variety tests conducted by the New Jersey Experiment Station during the three years 1897-1899 with Green Flageolet, Currie's Rust-proof, Early Mohawk, Golden Wax, Extra Early Refugee and Saddleback Wax, showed the Green Flageolet the most susceptible, and the Early Refugee the least.

WILT OF THE CUCUMBER, CANTALOUPE AND SQUASH.

With the appearance of a rust resistant cantaloupe in 1905, the history of which has been published by Mr. P. K. Blinn,* one of the greatest terrors to cantaloupe growing disappeared.

There is, however, a bacterial wilt which is frequently met with on cucurbits and which has been especially severe in its ravages upon the Hubbard squash. It frequently happens that the cantaloupe and cucumber are also attacked, the greatest damage occurring early in the season when the vines are just beginning to run. This disease is easily told from all other ailments of the cucurbits in that it is characterized by a wilting of the vine, pure and simple, without any visible external causes, such as rust or leaf spot. The symptoms are the sudden wilting of the leaves and runners as from lack of water or too hot sun, the runner becoming prostrate on the ground. From two to three days usually elapse before the wilting of the whole vine is complete and it is sometimes longer. It may remain in this wilted condition for several days, after which the leaves begin to dry up and ultimately die. Usually, one runner will die at a time, beginning at the tip and working back toward the root. There is no discoloration or other injury to the leaves; they simply wilt, dry up and retain their green color for considerable time.

A microscopic examination of a cross section of a wilted runner, taken near the root, or from the root iself, will show the water tubes leading out into the wilted vine to be literally clogged with bacteria. Under such conditions, the plants can get no water from the soil and a natural wilting follows. A very simple field test, and at the same time a reasonably reliable one, is to cut off a piece of a wilted runner close to the root, cut it in two crosswise and gently squeeze the freshly cut ends between the fingers; a semi-viscid liquid will ooze out from the cut surfaces and if these be rubbed together

*Bull. 103, Colo. Expt. Sta.

gently and slowly separated, this sticky liquid will string out in fine threads an inch and a half or more in length. The juices in the healthy, normal stem do not possess this viscid nature to such a degree and this phenomenon may be taken as an indication of the bacterial wilt.

Growers seem to think the disease is worse during wet weather and just after a heavy rain, especially if the sun comes out very hot. If such is the case, it is probably due to the fact that these conditions favor the growth of the germs and bring about a more rapid distribution of the bacteria through the plant.

The microorganism which causes the disease, *Bacillus tracheiphilus* (Smith), lives in the soil, in the decaying leaves and vines of the different cucurbits and probably gains entrance into the host plant through the root or some injured spot on the runner. Plant on new land as far as possible and avoid the use of fields which have shown the infection. In all probability, wilt lives in the soil for five to ten years and perhaps longer. For this reason no squash or other member of that family, which will furnish food for the germs, should be grown on sick land during this time. While rotation with other crops is in no sense a cure for the diseased soil, it is to be strongly recommended over attempting to grow cantaloupes or squash year after year, in spite of the disease.

Careful observations have shown that when only a few vines are affected, the disease is often spread over the whole field by the cucumber beetle and squash bug, hence the necessity of destroying these insects. While no direct benefit is derived from spraying, so far as killing the germs of the wilt is concerned, good often follows such treatment, because of the destruction of insects which carry the disease from plant to plant. Since no specific remedy can be recommended and no wilt resistant varieties can be offered, preventative measures alone are left at our disposal. Where the infection is not too general and it is confined to a few hills, further spread can often be prevented by digging up the vines and *burning them.*

NOTE—It is earnestly desired that the farmers, gardeners and fruit growers of the State of Colorado will co-operate with the Experiment Station in furthering the study of bacterial plant diseases by reporting all diseases of this nature that may come under their notice, and also by sending in specimens of suspicious material for examination. Wherever possible, the whole plant should be sent, for usually root, stem and leaf are required for a satisfactory diagnosis. Address communications relative to suspected bacterial plant diseases to,

BACTERIOLOGIST,
Agricultural Experiment Station,
Fort Collins, Colorado.